ACEEE

*Proc. of Int. Conf. on Recent Trends in Power, Control and Instrumentation Engineering*

# Power Quality Monitoring by Disturbance Detection using Hilbert Phase Shifting

D. P. Mishra[1] and C.K Samanta[2]
[1]International Institute of Information Technology /EEE department, Bhubaneswar, India
Email: Debani@iiit-bh.ac.in
[2] B.I.E.T Bhadrak /EE department, Bhadrak, India
Email: chandan.samanta71@gmail.com

*Abstract*—**This paper presents an innovative approach for the analysis of the Power Quality Disturbances both qualitatively and quantitatively. The proposed method employs the phase shifting property of Hilbert Transform for the accurate detection and computation of the characteristic magnitudes of the power quality disturbances along with the time of their occurrence. This facilitates for the real time detection and characterization of various disturbances such as voltage swells, voltage sags, voltage fluctuation, harmonics and transient oscillation accurately. The various disturbances have been simulated on the LabVIEW platform and the phase shifting property of Hilbert Transform has given satisfactory results. Real Time Signals were generated and digitalized by the aid of Data Acquisition (DAQ) card, which were processed in the LabVIEW environment, to yield immaculate results indicating the characteristic magnitudes and time of occurrence of disturbances.**

*Index Terms*—**Power Quality Monitoring, disturbance detection, Hilbert transform, phase shifting, LabVIEW**

## I. INTRODUCTION

The introduction of Power Electronics equipment in power systems and also the increased usage of various time varying and typical loads at the consumer end has resulted in disturbances in the Power Quality which are diverse and significant. The disturbances broadly fall in the category of voltage swells, voltage sags, voltage fluctuation, harmonics, inter-harmonics and transient oscillation. The research undertaken in power quality till date was successful in providing tools to detect and monitor each of the disturbances discretely and individually, but no effective common technique has been formulated to accurately detect and classify the disturbances in real time [1]-[2].

The typical detection methods involved are based on time domain methods or frequency domain methods making them suitable to detect only a characteristic type of disturbance at a given instant. The proposed method of application of phase shifting property of Hilbert transform is inherently a steady inter-convertible from time and frequency domain making it an efficient technique for the detection of disturbances of a wide range with uncharacteristic properties. The method even provides with the time of occurrence of the disturbance making it suitable for real time application. Coupling the same with LabVIEW platform and executing the method has given satisfactory results.

*DOI: 03.LSCS.2013.7.517*

## II. HILBERT TRANSFROM OVERVIEW

The HT of the function x(t) is defined as the convolution between x(t) and h(t) = $\frac{1}{\pi t}$ . The expression is

H[x (t)] = $x^h$(t) = x(t)*h(t)= x(t)* $\frac{1}{\pi t}$

$$= \frac{1}{\Pi} \int_{-\infty}^{\infty} \frac{x(\tau)}{t-\tau} d\tau \qquad (1)$$

In formula (1), * represent convolution; H[x(t)] and $x^h$(t) represent a HT in time-domain. Different from other transform methods, the HT of time-domain function is still in time domain, the HT in frequency domain can be expressed as

$$X^h(f) = X(f)H(f) \qquad (2)$$

Because the FT of h(t) ,

$F[h(t)] \equiv H(f) = -j\,\mathrm{sgn}(f) = -j\{\begin{matrix} 1, f > 0 \\ -1, f < 0 \end{matrix}$ (Sgn is the sign function ),

So as long as multiply the negative frequency of the X(f) by j and multiply positive frequency of the X(f) by -j , it can obtain HT on frequency- domain .
The HT result can be deduced from FT, So

$$x^h(t) = x(t) * h(t) = F^{-1}[X(f)H(f)] \qquad (3)$$

As input signal $x(t) = \sin(2\pi f_i t)$ , its FT

$X(f) = j/2[\delta(f + f_i) - \delta(f - f_i)]$, and multiply the negative frequency of the X(f) by j and multiply positive frequency of the X(f) by –j

$$X^h(f) = \frac{1}{2}[-\delta(f + f_i) - \delta(f - f_i)] = F[-\cos(2\pi f_i t)] \qquad (4)$$

Take Fourier inversion to both sides of the formula 4:

$$H[\sin(2\pi f_i t)] = -\cos(2\pi f_i t) \qquad (5)$$

Formula (5) shows HT of the sine function is the negative cosine function, the result also shows that it makes -j phase- shifting to the input signal. The same argument if input signal is the cosine function, the HT of the function is the sine function, the result shows that it makes -j phase- shifting to the input signal too. So the HT can provide $90^\circ$ phase-shifting and not influence the amplitude of the frequency–spectrum components [3].

## III. BASIC PRINCIPLE OF PHASE SHIFTING DETECTION

The ideal signal of power system is the pure sine waveform

$$u(t) = A\sin(2\pi f_0 t + \varphi_0) = A\sin(\omega_0 t + \varphi_0) \qquad (6)$$

In formula (6): A is the voltage amplitude; $f_0$ is the basic frequency: 50Hz; $\varphi_0$ is the initial phase.
In ideal conditions, the properties of u(t) are

$$\begin{aligned} & u^2(t) + u^2(t - T/4) \\ & = [A\sin(\omega_0 t + \varphi_0)]^2 + [A\sin(\omega_0(t - T/4) + \varphi_0)]^2 \\ & = A^2 \end{aligned} \qquad (7)$$

When the detection output y(t):

$$y(t) = u^2(t) + u^2(t - T/4) - A^2 \quad (8)$$

Apparently, if input signal is the ideal waveform the detection output y(t) is zero. However when the input signal contains disturbances, the expression is

$$u(t) = A\sin(\omega_0 t + \varphi_0) + e(t) \quad (9)$$

After $90^{\circ}$ phase-shifting to the u(t):

$$u_2(t) = u(t - T/4) = A\sin(\omega_0 t + \varphi_0 - 90^{\circ}) + e(t - 90^{\circ}) \quad (10)$$

The detection output y(t):

$$\begin{aligned} y(t) &= u^2(t) + u^2(t - T/4) - A^2 \\ &= 2A\sin(\omega_0 t + \varphi_0) * e(t) \\ &+ 2A\cos(\omega_0 t + \varphi_0) * e(t - 90^{\circ}) \\ &+ e^2(t) + e^2(t - 90^{\circ}) \end{aligned} \quad (11)$$

In the formula 11, $A\sin(\omega_0 t + \varphi_0)$ and $A\cos(\omega_0 t + \varphi_0)$ are known, so

$$y(t) = \xi(e(t)) \quad (12)$$

So when there are disturbances in the input signal, the detection output signal, the detection output certainly cannot be equal to zero. Furthermore e(t) will have different value when the disturbances input are different and detection output will have different waveform characteristics, if it is corresponding to the time when disturbances take place, it can assure the detection's real-time characteristic[3].

## IV. SIMULATED DISTRUBANCE AND RESULTS

Various Power Quality disturbances like voltage swells, voltage sags, voltage fluctuation, harmonics, inter-harmonics and transient oscillation have been simulated and their real time detection was successful done.

### *A. Ideal waveform generation*

An ideal waveform is generated in mat lab of frequency 50 Hz, amplitude 1, sampling frequency 6400 Hz and number of samples 1280. When an ideal waveform with no distortion is given to Hilbert detector, the simulation shows a straight line, i.e., zero distortion. The ideal waveform is shown in "Fig.1" and the zero distortion output is shown in "Fig.2".

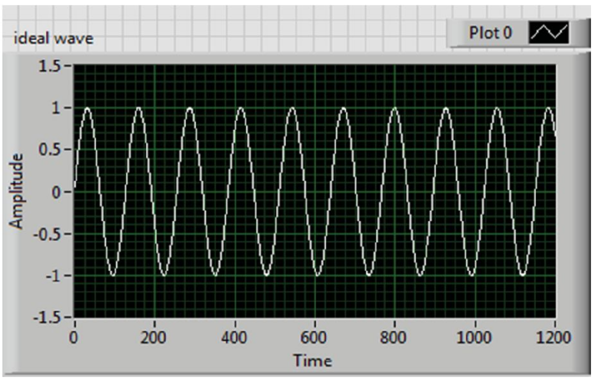


Figure1. Ideal Waveform

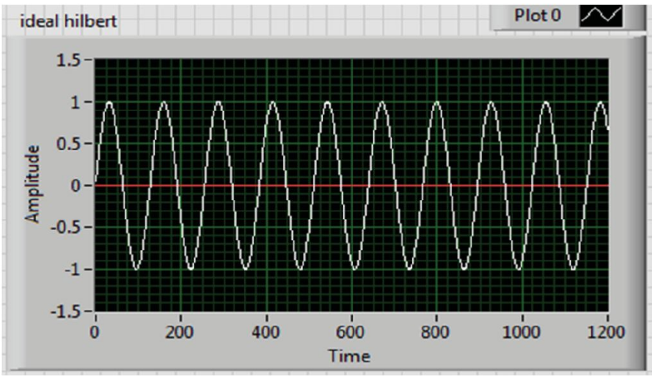


Figure2. Zero Distortion Output waveform

*B. Voltage Swells and Voltage sags waveform*

$$u(t) = (1 \pm \alpha(\mu(t - t_1) - \mu(t - t_2)))\sin(\omega_0 t) \qquad (13)$$

In formula (13), $u(\tau) = \begin{cases} 0, t \le 0 \\ 1, t > 0 \end{cases}$ is the unit step functions, $\alpha = 0.1 \sim 0.9$ Is the voltage swells (voltage dips) amplitude; $0.5T < t_2 - t_1 < 30T$ is the voltage swells (voltage dips) durations; $t_1$ is the voltage swells (voltage dips) initial time, $t_2$ is the end time.[4]-[5] Here, a voltage swell signal is generated, using LabVIEW, whose amplitude is 1.9 times the normal amplitude during disturbance. Simulation results show that voltage swell occurs during the samples 320 to 700. When the distorted waveform is fed into the HT detector, a swell is seen during the disturbance. HT accurately detects the amplitude, duration and time of the voltage swell. “Fig.3” shows the voltage swell in the generated wave and “Fig.4” shows the output of the voltage swell after phase shift.

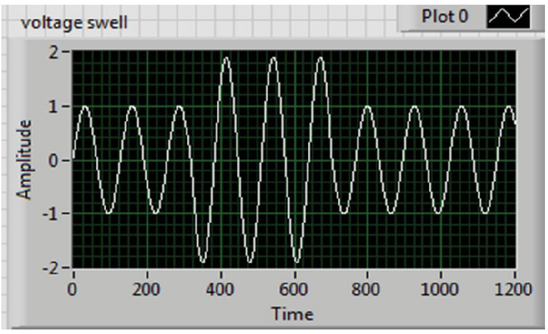


Figure3. Voltage swells generation

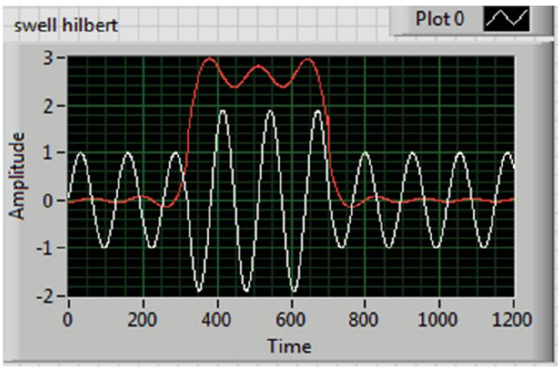


Figure4.Output of Voltage Swell after HT

A voltage sag signal of amplitude 0.2 times the normal amplitude during disturbance is generated and fed into the Hilbert detector. The simulation results show that sag occurs during the samples 320 to 705. “Fig.5” shows the voltage sag generation and “Fig.6” demonstrates the sag detection.

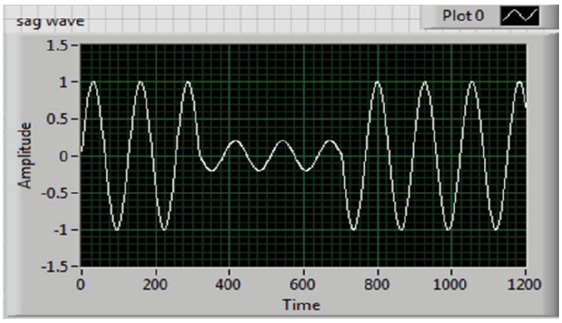


Figure5. Voltage sags generation

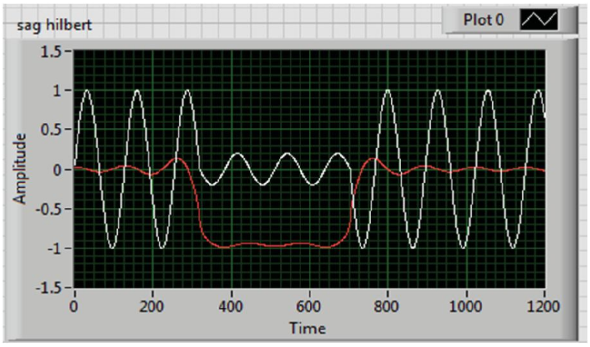


Figure6.Voltage sag Detection

### C. Voltage Fluctuation

$$u(t) = (1 + \alpha \sin(\beta\omega_0 t)) * \sin(\omega_0 t) \tag{14}$$

In formula (14), $\alpha = 0.1 \sim 0.2$ is the fluctuation range; $\alpha = 0.1 \sim 0.5$ is the fluctuation frequency relative coefficient. A voltage fluctuation signal is generated using the equation (14), where the value of α=0.170 and β=0.206. The sampling info contains sampling frequency (6400 Hz) and number of samples 1280. Simulation results show a periodically fluctuating wave. The timed delay is taken to be 0.1secs. “Fig.7” shows the input data for voltage fluctuation, “Fig.8” shows the Voltage fluctuation waveform and “Fig.9” shows the Output waveform for Voltage fluctuation.[7]

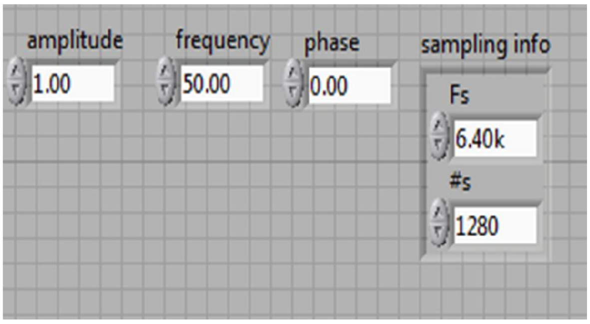


Figure7. Input data for Voltage Fluctuation

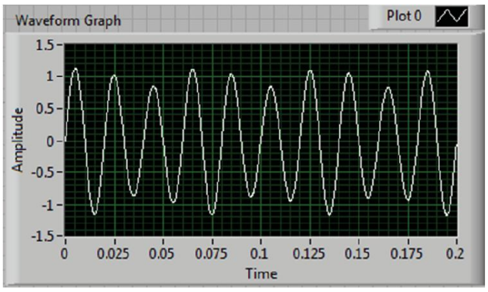


Figure8.Voltage Fluctuation Waveform

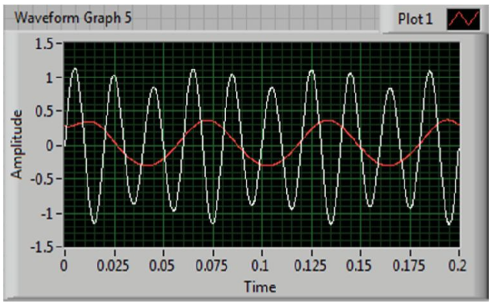


Figure9.Output Waveform for Voltage Fluctuation

*D. Harmonics*

$$u(t) = \sin(\omega_0 t) + \alpha_3 \sin(3\omega_0 t) + \alpha_5 \sin(5\omega_0 t) + \alpha_7 \sin(7\omega_0 t) \quad (15)$$

A distorted harmonic waveform is created by adding 3$^{rd}$, 5$^{th}$, 7th and 9$^{th}$ harmonics to the ideal waveform. Results for detected output wave are given below in “Fig. 10” and “Fig.11”.[6]

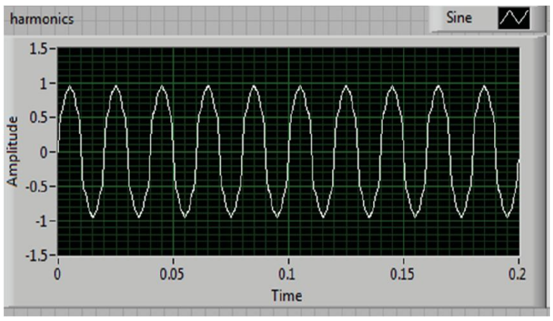


Figure10.The Generated wave with harmonics

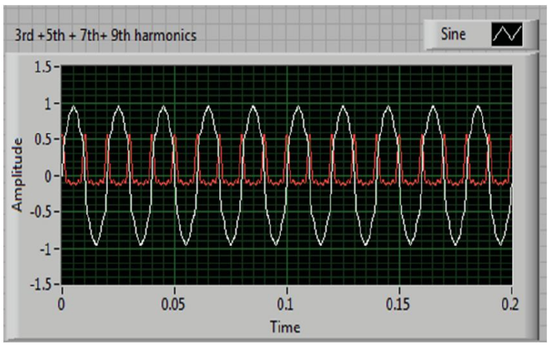


Figure11.Output wave with harmonics

*E. Frequency fluctuation*

In frequency fluctuation generation, during interval 450 to 700, signal of three times the normal frequency is added to the signal. Simulation results show greater fluctuations during that interval in “Fig.12” and “Fig.13”.

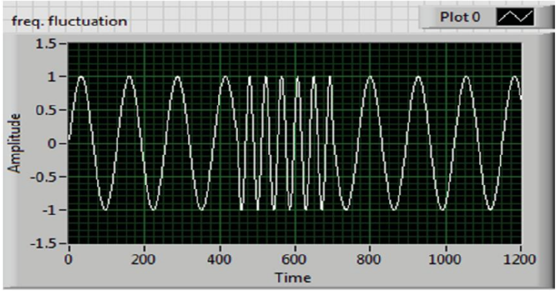


Figure12.The input wave for frequency fluctuation

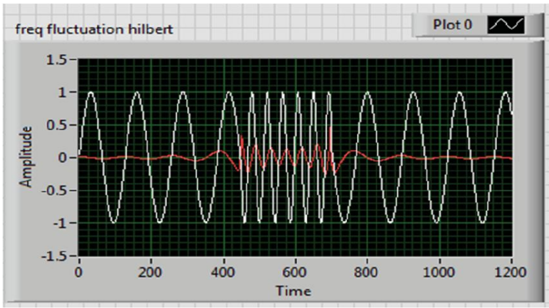


Figure13.The output wave for frequency fluctuation

*F. Notch*

A notch denotes a disturbance that occurs for a very short duration. Hence, a signal is generated with disturbance at only one sample. Its simulation result shown below depicts a disturbance at sample 420 in “Fig. 14” and “Fig.15”.

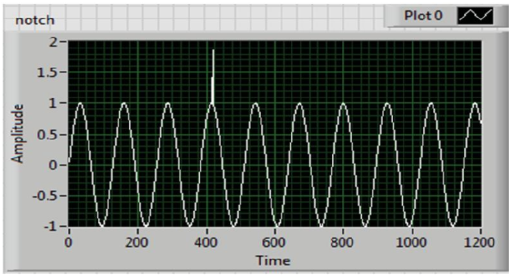


Figure14.Input Waveform for notch

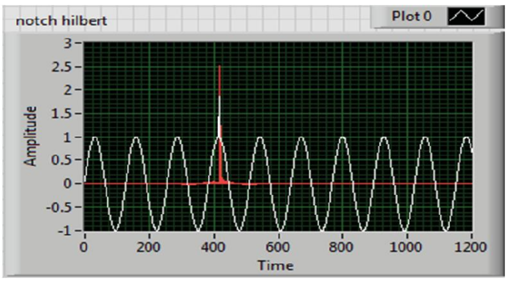


Figure15.Output Waveform for notch

*G. Momentary Interruption*

Momentary interruption means that a signal is interrupted during that time interval, i.e., signal is zero during that time interval. After executing the code, simulation shows error between samples 350 and 480. Figure 16 and Figure 17 depict the aspects of Momentary Interruption.[8]

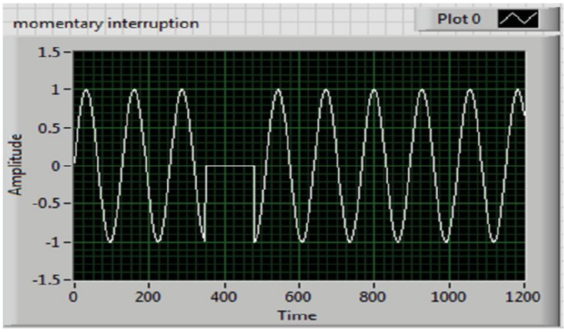


Figure16.Input Momentary Interruption Waveform

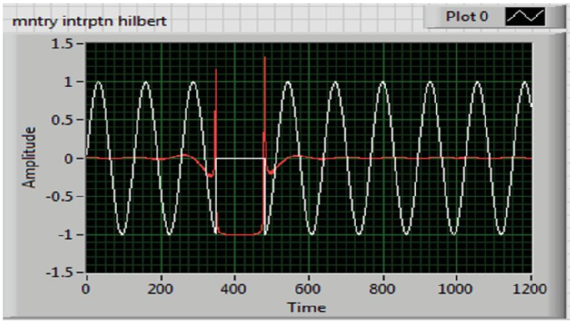


Figure17.Output Momentary Interruption Waveform

## V. CONCLUSIONS

The phase shifting property of Hilbert Transform has been employed to detect and classify various faults in this paper. Disturbances such as voltage swells, voltage sags, voltage fluctuation, harmonics, inter-harmonics, transient oscillation, frequency fluctuation, notch and momentary interruption have been simulated and results have been found to be accurate with respect to detection of the faults, finding out their characteristic magnitudes and time of their occurrence. The method is hence suitable for Real-time application for the detection of faults as the time of occurrence is precisely detected.

## REFERENCES


[1] Ding Yifeng, Cheng Haozhong, Zhan Yong, Sun Yibin, Yan Jiangyong. ‘Present status and development in power quality monitoring’, *Electric Power,* 2004,37(7):16-19

[2] Priyanka Roy, Sankhadip Saha, Mrityunjay Kumar Ray, Madhurima Chattopadhya, Parimal Acharjee, “Real Time Monitoring and Analysis of Signal Harmonics for Non-Linear Loads Using Virtual Instrument” *IEEE - International Conference On Advances In Engineering, Science And Management (ICAESM -2012) March 30, 31, 2012.*

[3] Luo An. ‘Control of power network and reactive compensate technical and equipment [M]’, Beijing: *Electric Power*, 2006.

[4] D. P. Mishra, “Sag, Swell and Interruption Detection Using Wavelet in LabVIEW” , International Journal of Computer and Electrical Engineering, Vol. 5, No. 4, August 2013.

[5] Cheng-I Chen, Member, IEEE, Hung-Lu Wang, and Yuan-Chieh Chin, Non-Member “A Simple Rule-Based Approach for Detection and Classification of Voltage Sag, Swell, and Interruption in Power Systems” *IEEE PEDS 2011, Singapore, 5 - 8 December 2011.*

[6] Dr. R.K. Tripathi, Member, IEEE & Mr. Chandreshver Pratap Singh, “Power Quality Control of Unregulated Non-linear Loads*”,978-1-4244-8542-0/10, 2010 IEEE.*

[7] Vinay Dwivedi, Dheerendra Singh, “Electric Power Quality Monitoring (PQM) using Virtual Instrumentation”, *SPEEDAM 2010 International Symposium on Power Electronics, Electrical Drives, Automation and Motion.*

[8] ZHAO Cheng-yong, GAO Ben-fang, JIA Xiu-fang. ‘Comprehensive power quality detecting system based on LabVIEW’, *Journal of North China, Electric Power University* 2006 33(2) 63-6